DECISION MAKER

Real problem solving with your micro

BRAINPOWER

Application through learning

DECISION MAKER

Real problem solving with your micro

Text book by Stuart Armstrong

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SOFT

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Getting Started

Decision Maker has been designed to cater for people with a wide range of backgrounds and skills. Many of you will therefore not need to read through this text from cover to cover in order to use the computer programs. To accelerate your progress, we suggest the following:

A. If you already understand the principles of Decision Analysis and Decision Trees, simply turn the book around, and find Chapter 12, where you will be given detailed instructions on how to use the Applications Program. A summary of the program keywords is given in Appendix 3.

B. If you understand what Decision Analysis is, but don't know how to apply it, then turn to Chapter 1, and follow the instructions on how to use the Teaching Program.

C. If you are starting from scratch, if you don't have your computer handy, or if you simply want to take a more leisurely approach, then please read through the Introduction before you go any further.

NOTE

If you are not familiar with the procedures required to load the Teaching or Applications Program onto your computer, refer to Appendix 2, where you will find specific instructions for using the different versions of **Decision Maker.**

Contents

The book is laid out in a way which allows you to stand it upright in the box lid alongside your computer. For this reason, the pages are in an unusual sequence. Pages 1 to 26 start from the front of the book, whilst to use pages 27 to 53 just turn the book around and start from the back.

Introduction

Welcome

Titles in the **BRAINPOWER** series are uniquely designed to harness the power of your home computer to enable you to learn new skills in a simpler and more enjoyable way. The sophisticated interactive approach ensures that you can work at your own pace and, once you have mastered the topic, the applications program will continue to serve your needs. We have made every effort to create a course which is straightforward to use, but if you think that we could improve upon it, please write to us on the card included in the pack.

Decision Maker is a complete learning and applications course based upon the theory of Decision Analysis and Decision Trees. Your purchase consists of three elements:

1) The Text Book which you are now reading. Please bear in mind that you will be using it continuously in conjunction with the computer, and therefore it has been designed to stand upright in the box lid so that you can refer to it more easily.

2) The Teaching Program, which will be used to give you a full understanding of the concepts of Decision Analysis.

3) The Applications Program, which you will be able to use to solve your own decision analysis problems.

You will find that the Teaching Program is not a simple tutorial on how to use the Applications Program. Once you gain an understanding of the material, you will be able to use decision analysis to solve problems with or without your computer.

If you think that you already have a sound grasp of the principles of decision analysis, then you may wish to try out the Applications Program immediately. If so, simply turn the book around, and find Chapter 12. There you will discover the detailed instructions for solving your own decision problems.

Decision Analysis

The techniques presented in **Decision Maker** can be used to perform an explicit analysis of a particular situation, and reveal the appropriate strategy to adopt. Your role as decision maker is simplified because you can see how various actions taken now generate different outcomes in the future. It is this structuring of the decision problem, combined with a

means to measure the value of the decision which is the key attribute of Decision Analysis. You can "unbundle" the problem – breaking it down into sequential component parts, and this process will lead you to a more enlightened view of the options, allowing you to take greater control over the pattern of future events.

Decision Maker is a powerful tool for anyone interested in strategy and decisions in all walks of life, who wants to minimise the risks involved. Even at their most basic, these procedures will allow you to project yourself into the future with confidence and dexterity, assured of a more logical understanding of the problem addressed and its solution in terms of your own requirements.

For the newcomer to this topic, we should explain what kinds of problem can be solved by decision analysis and how the process is applied. It is important to appreciate that not all decision making problems can be easily resolved by this method. Other techniques, such as Linear Programming, Discounted Cash Flows, Critical Path Analysis and so on are more appropriate for some situations. To use decision analysis, it must be possible to break the problem down into a finite number of elements in the following way:

1) There is an initial decision to make, and there is a limited number of clearly defined alternatives from which to choose.

2) For each decision, there is a limited number of possible alternative outcomes.

3) Each outcome could lead to another decision with another series of possible alternative outcomes, and so on.

The technique of analysing the decision involves drawing a diagram of the process in a symbolic form. In fact the actual process of constructing the diagram, known as a "Decision Tree", will help to make a very complex decision look somewhat simpler.

Once the problem is dissected in this way, we need a means of judging the value of the decision. In business, this is usually measured by cost or profit, but in other circumstances, the value could be assessed, for instance in terms of the number of lives saved, or the number of jobs created or some other non-cash figure. We must then be able to estimate the "value" of each decision and outcome, so that the initial decision which leads to the highest value can be selected.

The application of **Decision Maker** techniques to a wide range of situations is a powerful management tool for a number of reasons:

1) It compels you, the person making the decision, to recognise the

structure of, and the relationships between the elements involved.

2) You must systematically value all of the possible actions and outcomes, and once again this demands that you consciously review each aspect of the decision.

3) You can modify the costs, values and risks of the various activities involved and test them to find out how much things need to change to make you alter your initial decision.

In summary, **Decision Maker** will provide you with the skills to apply this sophisticated technique to a multitude of decision problems, both in the home and at work, and will enable you to take full advantage of the investment you have made in your microcomputer.

The actual procedure is really quite straightforward, but do not be concerned if you are a little confused by this first explanation of the process, because the Teaching Program will work through it all in rational stages.

CHAPTER 1

The Teaching Method

1.1 Teaching Method

Before we move into the stage of actually learning anything, we will quickly review how the computer is going to be used in conjunction with this book. First of all, you will find that all written explanations of the subject will appear in the book. We don't think that you want to strain your eyes reading computer screens full of text, and anyway computer memory is a relatively expensive medium for storing the written word. Because of this principle, you will be switching back and forth between book and screen all the time, so set up the book on it's stand next to the computer where you can refer from one to the other easily. You will find it useful to have a pencil and paper handy as well. The screen will be used to show you examples in operation and to present you with exercises so that you can check your own understanding.

As you work your way through the book, you will be asked to operate the computer by pressing certain keys. This is so that the computer knows which point you have reached. Any key you need to press will be highlighted in the text in colour such as **SPACE** or **4.** Likewise, when the computer wants you to return to the book, it will direct you to your place by giving you the number of the relevant chapter sub-heading.

1.2 The Six Step Process

Decision Analysis can be thought of as a six step process, leading from a general concept of the nature of the decision through to a specific solution. Each step will be explained briefly in the worked example demonstrated in Chapter 2, and then covered in detail in the subsequent teaching chapters. The steps can be defined as follows:

1) STRUCTURE – Sort out what the various decisions are that have to be made, in what order they arise, and what chance events occur in between. The various decisions and outcomes are then drawn out in a symbolic form, called a "Decision Tree". – This is explained in Chapter 3 of the book.

2) PAYOFFS – Work out the costs and values of all the events involved. – Explained in Chapter 4.

3) PROBABILITIES – Estimate the likelihood of each of the chance events occuring. – Explained in Chapter 5.

4) ROLL-BACK – Use the decision tree analysis rules to calculate the

solution. – This is the key step of the process, and it is explained in Chapters 6 and 7.

5) RISK ANALYSIS – Check out the calculated solution to ensure that all possible outcomes can be tolerated. – Chapter 8.

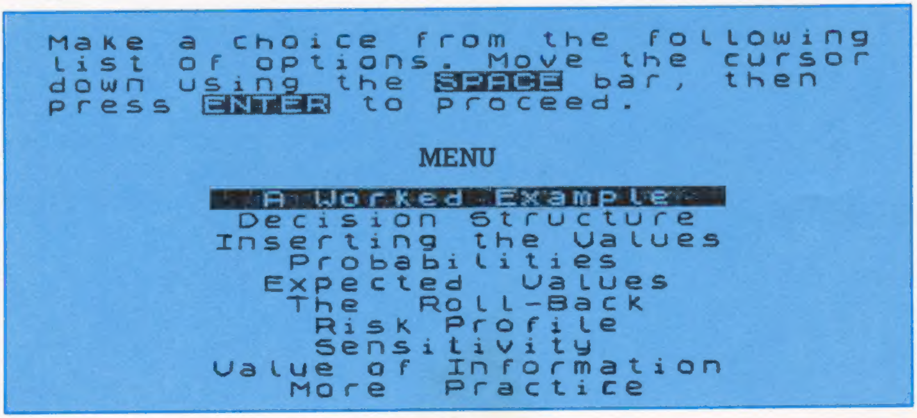
6) SENSITIVITY ANALYSIS – Find out how much your assumptions have to be changed to change the solution. – Chapter 9.

There is also a chapter on the concept of "Value of Information", a more sophisticated concept which only becomes relevant once a decision can be analysed in detail.

1.3 Getting Started

Instruct your computer to load in the Teaching Program. If you are a newcomer to computers, there are some reminders for you in Appendix 2. The Program will start automatically, and when you press the SPACE key, it will display a list of options from which you can choose. The options relate to the Chapter headings in the text book. You make your choice by using the SPACE and RETURN (or ENTER) keys. Each time you press SPACE, the black bar will move one step down the list, and if it is at the bottom, it will jump to the top. When the bar is on the item you wish to select, press the ENTER (or RETURN) key, and the computer will act on your choice. This type of selection list will be referred to as a **MENU** from now on.

When you use the program for the first time, you should select the first option, "A WORKED EXAMPLE", from the menu, but on subsequent occasions, you can choose the option for the particular unit you wish to study.



Once an option has been selected, the computer will have to load another section of the program. If you are using a cassette tape recorder, this can take quite a long time, particularly for the later topics, and the more experienced user may wish to refer to Appendix 2, which suggests a way of speeding up the process.

When the correct section is loaded, the computer will give a message confirming the name of the unit and it will point you to the correct chapter in the book. Once any one unit is completed, the program will always give you the option of repeating the unit, stopping, or going on to the next unit. From time to time, instructions will be displayed on the screen which are not mentioned in the book. Always read and follow these instructions carefully.

Before you begin, remember to equip yourself with a pencil and paper, in order that you can make notes and sketches as you go. You should also be prepared to concentrate on a unit for quite a long period of time, for although we have made each step as simple as possible this is not a trivial subject to study. There will be plenty of opportunities to rework sections and ensure complete understanding, and of course plenty of practice to build your confidence.

CHAPTER 2

A Worked Example

2.1 The Problem

Let us assume that you have decided to buy a five year old Ford Escort, and you only have a choice of two cars. They both look exactly the same, but the prices are different. The first one will cost you £1000 from your local garage, and it comes with a full guarantee. That is, if it breaks down, they will repair it. The second car is being offered as a private sale for only £600, but of course, if it breaks down, the repairs are your responsibility. If it does go wrong, you can choose either to have it repaired or to resell it.

Before we go through and solve this problem, remember that this is simply an example of how the method is applied. If there is anything which you do not understand as you go through it, don't ponder too deeply over it. Go through to the finish, and then move on to the main part of the Teaching Program.

2.2 Laying out the Tree

We are now going to use the computer screen to draw an example of a decision tree. First load the teaching program, and select the **WORKED EXAMPLE** option from the menu. When the computer is ready, follow the text and press the keys in the sequence shown to build up the tree one step at a time.

Start the computer program by typing the letters G O on the keyboard. The first thing which the computer draws on the screen is a square box. On our diagram, the box will be the standard symbol used to represent a point in time when a decision is to be made. Initially, we can make one of two decisions, so we draw in a line representing each – press **1**. We can buy the guaranteed car, or the cheap car.

If we choose the guaranteed car, then we can assume that there will be no more to worry about, so we end the line with a bar – press **2**. With the cheap car, on the other hand, there is more to consider. It may be OK, but it may break down, and if it does, it's your problem. Therefore, we invent a new symbol to represent a "chance" event, that is, one over which we have no control – press 3, and you will see a circle. Either it will be no problem, or it will break down – press 4. If it doesn't break down, there is no more to worry about, and we can end that line with a bar. But if it breaks down, we have another decision to make – press 5.

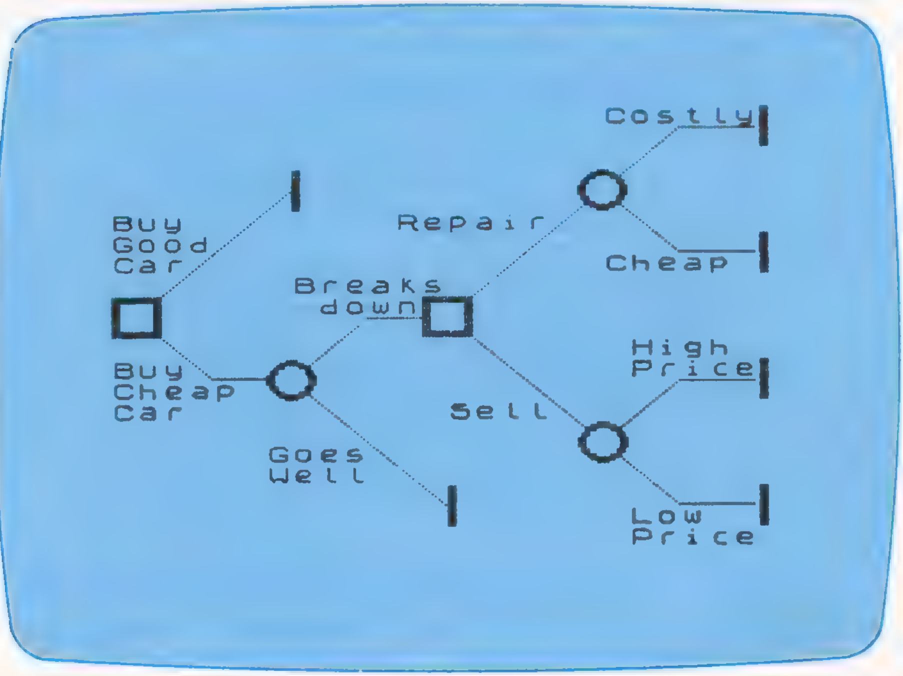
We can now choose between getting it repaired and selling it, so we can add two more lines to the picture – press 6. To make the problem simple, we will assume that we don't know in advance how much the car will cost to repair or how much we can sell it for. These are two more

chances we will have to accept – press 7.

The repairs could either be costly or cheap – press 8 – and we could either get a high or low price if we sell – press 9. Now we assume that if we have to get the car fixed, it will be OK from then onward, but if we decide to sell it, we will simply be able to replace it with the £1000 car which we were offered in the first place, so we can end all the lines with a bar – press 0.

Well, that's step one completed. We have worked out the sequence of events and drawn a diagram to represent it. For obvious reasons, this diagram is called a **DECISION TREE**. Each of the **DECISION** and **CHANCE** points on the tree is known as a **NODE**, whilst each of the lines which describes an event is called a **BRANCH**.

If you are a little uncertain about the procedure up to this point, the computer offers you the facility to rerun the process of laying out the tree. Otherwise, leave the computer and read on:



2.3 Adding the Information

For many complex decisions, the process of drawing the tree itself will help a great deal in resolving the problem. But to reach a conclusion, we must find a way to value each decision. In the used car example, the normal approach would be to find the lowest cost solution, and that is what we will do next. This is our "Decision Criterion" – we want to find the cheapest answer.

If you look at the tree we have drawn, you will see that it has six "endings", which represent the six possible final outcomes which can arise from the decisions we have chosen to make. You can trace out on the tree how each outcome could occur as follows:

1) We buy the guaranteed car, and there is no more to worry about;
   or
2) We buy the cheap which turns out to go well, and there is no more to worry about;
   or
3) We buy the cheap car, it breaks down, we repair it and it costs a lot of money;
   or
4) We buy the cheap car, it breaks down and we have it repaired for a low price;
   or
5) The cheap car breaks down and we sell it for a profit, putting the money towards buying the guaranteed car;
   or finally
6) The cheap car breaks down, we lose money on selling it and we buy the guaranteed car.

We must now perform step two of the process, working out how much each outcome will cost us. We lay out all the individual costs involved as follows:

Buying the guaranteed car	£1000
Buying the cheap car	£ 600
Expensive car repairs cost	£1000
Inexpensive car repairs cost	£ 300
High resale price of car	£ 800
Low resale price of car	£ 400

You can see that some of these figures represent costs which we cannot "know" in advance. We have had to make the best subjective estimates we can achieve. Although this may sound like a difficult problem, in most

situations the people involved usually have a reasonably good idea of what the various outcomes may cost or what profits they may generate. If you are not certain, it is a simple matter to rework the problem with different costs to see how much that changes things.

These figures can be combined to find out how much each outcome will cost us. For instance, the expensive repair branch will have cost us £600 for the car plus £1000 for repairs, a total cost of £1600. The high price sale branch will have cost us £600 for the cheap car, then a gain of £800 from selling it and a payment of £1000 for the good car, a total cost of £800. All the other branches have costs which can be worked out in the same way. Try them for yourself and then press 1 for the computer to display the correct figures. You will notice that they are shown as negative amounts. This is because they are "costs". Positive values on the tree are used to represent revenues, that is money earned or received.

2.4 Probabilities

Step three involves determining one more piece of information before we solve the tree. You know that there are three "chance" nodes on the tree, depicted by circles. These are the places where we have no control over what will happen next, but we can make a good guess at which outcome is more likely at each node. For instance, we may think that the cheap car is more likely to break down than to go well. Let us say that there is a 70% chance of breakdown, which means there is only a 30% chance of it going well (remember that the two percentages must add up to 100%).

Likewise, we think that there is a 60% chance of repairing it cheaply if it does break down, and because we know that you are a good salesman, there is also a 60% chance of you being able to sell it for a higher price than you paid for it.

Before we use these probabilities, we convert them into decimal values. This is because the convention for probabilities is that they are represented by numbers in the range 0 to 1. For instance, 70% becomes 0.7, 40% becomes 0.4, and so on. In this way, 100% is represented as 1, therefore the rule that percentages must add to 100% becomes "Probabilities must add up to 1". So, press 2 to display the probabilities on the tree. You can see that the probabilities at each chance node add up to 1. As in the case of some of the cost figures which we used earlier, these probabilities represent our best guesses of what might occur.

2.5 Finding the Solution

Now we have enough information to perform step four, selecting the best decision, but this is the difficult step for the novice. Here we will just show you quickly HOW it is done. The program will explain WHY we do it this

way in a section further along. To arrive at the solution, we start at the right hand end of the screen, and calculate a value for each chance and decision node in a process known as the "roll-back". There are two rules, one for decision nodes and one for chance nodes.

RULE 1 – Chance nodes

To calculate the value of a chance node, multiply the value of each of the nodes immediately following by the probability of the event leading to it, and add the resulting figures together. e.g., consider the costly/cheap repair chance node. The two following nodes are the ends, with values of −£1600 and −£900 and probabilities of 40% and 60%. The value of the node is therefore:

$$-£1600 \times 40\% \text{ plus } -£900 \times 60\%$$

$$= -£640 - £540 = -£1180$$

– press 3 to display this result on the screen.

The high/low resale price chance can likewise be evaluated as follows:

$$-£800 \times 60\% \text{ plus } -£1200 \times 40\%$$

$$= -£480 - £480 = -£960$$

– press 4 to display this result as well.

RULE 2 – Decision nodes

The value of a decision node is equal to the best value of all the following nodes. The events leading to nodes of lesser values are eliminated as unsatisfactory options. e.g., the sell/repair decision can take the value of either −£1180 or −£960 from the following nodes. As these are costs in our example, the figures are negative and the best value is the lesser negative one, −£960. Therefore, the node has a value of −£960, and the "repair" option is eliminated. That is, if we were ever faced with this choice, we should always choose to sell. Press 5 to display this value. Note that the computer also draws a "bar" across the repair option, as this has now been deleted.

There are now only two nodes left to evaluate; the chance of breakdown,

and the initial buying decision. The chance node has a value of:

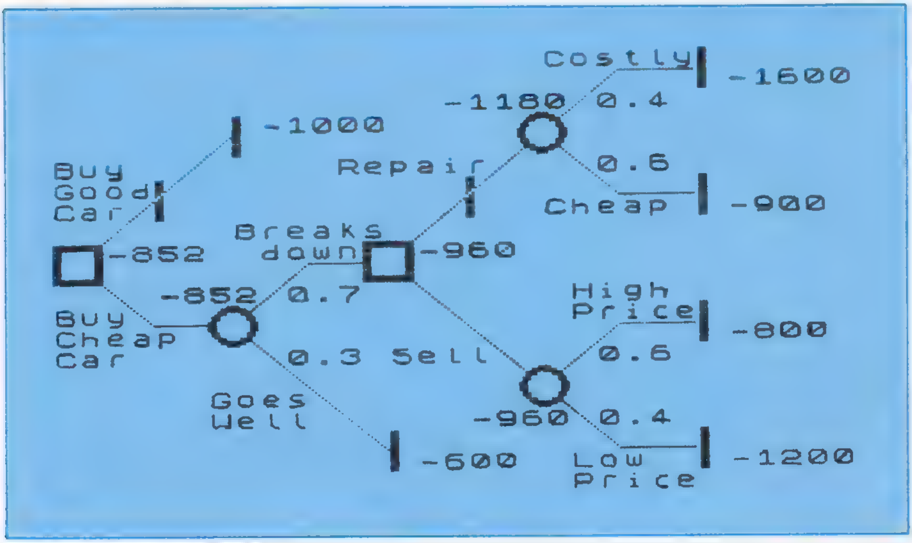
$$-£960 \times 70\% \text{ plus } -£600 \times 30\%$$

$$= -£672 - £180 = -£852$$

– Press 6 to display this.

And now you can see that the first decision can be given the value of either −£1000 (guaranteed car) or −£852 (cheap car). Therefore the cheap car option is selected, with a value of −£852, and the guaranteed car alternative is eliminated. Press 7 to display this final result.

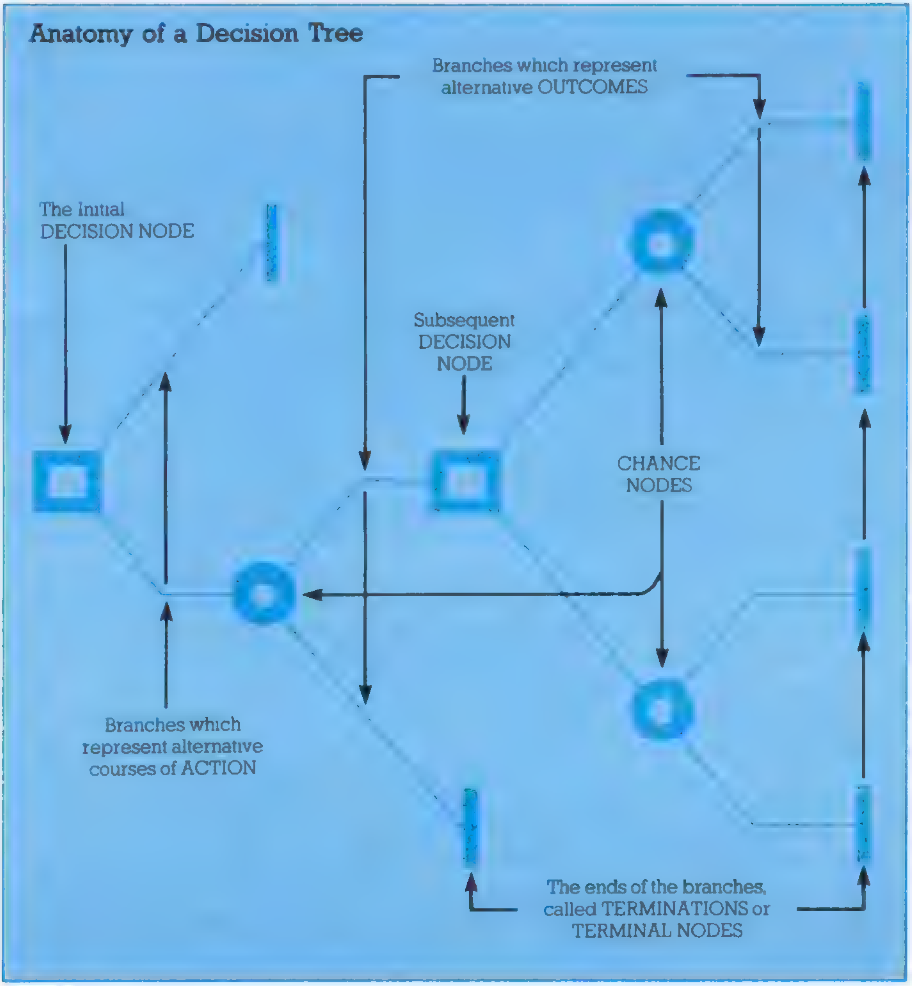
So, the tree tells us to buy the cheap car, and sell it again if it breaks down – it sounds like quite a reasonable answer to me!



2.6 What Now?

Well, if you followed the way in which we found a solution to the example, you should have now just about enough knowledge to try to solve your own trees. If, on the other hand, you are still worried, you need not be. This program goes on to explain each of the elements of decision analysis in more detail, and provides practice routines so that you can become completely familiar with the process. If you are ready to continue learning, select the option on the screen to move on to the next module, or you may like to run through this chapter again – it's up to you!

If you do feel bold enough to try a tree of your own, turn to Chapter 12 and follow the instructions to use the Applications Program. We suggest that you start by using the example problem we have just been through, and then try changing it around, perhaps by adding the "what if" alternatives you may feel appropriate. To make matters simpler for you, you will find that this, together with all the other examples used in the text, is summarised in Appendix 1 at the end of the manual. If you try the example we have been using, and find it a little too difficult, you can always come back to this point and continue from here.



CHAPTER 3

Decision Structure

3.1 Nodes & Branches

The example which we presented in Chapter 1 showed you how we can draw a "tree" to represent the series of decision points and chance events which make up a complex decision problem. Let us now think through the way in which the structure was formed. Type D S to display the example again. First of all, we recognised an initial point where we had a choice of action. We called this point a "Decision Node". From this node, led two branches representing the alternative courses of action. One branch simply came to an end because nothing further resulted from the action. The action represented by the other branch, however, led to the possibility of alternative outcomes; breakdown or no breakdown. These outcomes led in turn to another decision, or to no further action. In this way, the tree was constructed of four basic elements; two types of node and two types of branch. The two node types are represented by circles and squares, whilst the branch types depend upon the types of nodes they spring from;

ACTION branches originate from **DECISION** nodes.

OUTCOME branches originate from **CHANCE** nodes.

You can see the difference in the example on the computer screen. The computer will now be used to highlight the different branch types for you. Press 1 and follow the instructions at the top of the screen.

3.2 Choice & Chance

You will recognise that ACTIONS are the things that you can choose to do, whilst OUTCOMES are things that you cannot choose. Notice, however, that you may be able to influence some OUTCOMES. Your own actions can make certain outcomes more or less likely. For instance, the action of wearing a raincoat will not change the chance that it will rain, but it will have an effect on the chance that you will get wet.

Here is a simple exercise to test your understanding so far. The computer will draw a new decision tree about choosing whether to use the M4 or the M40 to drive out of London in the rush hour. It will then highlight various parts of the tree by flashing them on and off. You must decide whether the flashing element is a CHANCE NODE, a DECISION NODE, an ACTION or an OUTCOME. Tell the computer your answer by pressing C, D, A or O respectively. But first, press 2 to display the tree.

3.3 Review Problem

Now you can try drawing a tree of your own. Here is the simple problem:

> You are setting up a new computer showroom. One of the computer manufacturers, Microfruit plc, has offered you an agency for their range of two computers, the Avocado and the Banana. (We'll call them A and B from now on), but their proposal is a complex one structured to test your selling skills. You can choose to accept one type A *or* one type B computer only. If you sell it within a certain time limit, they will offer you one of the other type to sell. But if you fail, they will take the computer back and refuse to deal with you any more. On the other hand, if you sell the second one as well, they will make you a dealer. You are a little worried about the costs involved, and so you may choose to decline the offer immediately, or perhaps decline part way through. If you persevere and succeed, then you will automatically take up the dealership, and make an attractive profit.

Well, that is the decision which you have to structure. When you restart the computer, it will ask you what to do by showing you a series of alternatives and allowing you to make a choice. This list of choices is in the form of a "menu" at the bottom left of the screen, smaller but similar to the one you have already used to select this module. It works in exactly the same way as before. You will be asked to make a whole series of selections until finally the tree structure is complete. When you are ready, just press 3 to start work.

CHAPTER 4

Inserting The Values

4.1 Calculating the Payoffs

As we mentioned in the Introduction, the Decision Analysis method works on the basis of each of the outcomes having some measurable value. When you use the method, you compare these values and select the series of decisions which leads to the best result.

Once you have drawn a tree, it will have a number of endings, and you have to work out a value for each one. You do this by tracing your way through the tree from the starting decision, along the branches to the particular end of the tree which you want to value. The actions and outcomes along the way will have costs and values. If you add them all up as you go, you will have the value or cost of reaching the final result. This final value for each branch end is called its **PAYOFF**. We will now return to the used car example to demonstrate this more clearly. Remember that the figures involved were as follows:

Purchase of the Good Car	£1000
Purchase of the Cheap Car	£ 600
Costly Repairs	£1000
Cheap Repairs	£ 300
Low resale price and purchase of Good Car	£ 600
High resale price and purchase of the Good Car	£ 200

The computer will be used to redisplay the tree and calculate each payoff in turn, showing how it is done. The calculations will appear at the top right of the screen. Press I V to restart the computer.

TO CALCULATE THE PAYOFFS:

1. You must calculate the payoff for every terminated branch.
2. The payoff is the total amount that that particular end result would earn us or cost us. Remember that costs are negative.
3. Calculate the payoff by adding up the costs and values of all the branches that lead to that terminated branch.

4.2 Review Problem

It's now time to try an example of your own, so let us have another look at the Microfruit Dealer problem.

In addition to the structure of the tree which you have already resolved, you will need to know the costs and values of all the actions and outcomes. Well, here they are:

Cost of advertising the Avocado	£ 400
Cost of advertising the Banana	£ 500
Profit from selling the Avocado	£ 200
Profit from selling the Banana	£1000
Net Profit once dealership is acquired	£5000

Remember, if you choose to attempt to sell one of the computers, you will have to pay out the advertising costs associated with it whether you sell it or not. Profits are always considered as positive numbers, whilst costs are negative.

When you restart the computer, the procedure will be as follows:

1) The computer will identify a payoff point with a flashing question mark, and will ask you to select the events leading to it.

2) You will then be able to choose the events, one at a time, by following the instructions at the bottom of the screen. As you choose each event, it will ask for its value, which you can find from the list in the text. Don't forget that costs are negative and earnings are positive, and don't forget that some events may have zero values.

3) When you have told the computer that there are no more events leading to that payoff, it will calculate the answer from the figures you have given it.

4) Steps (1) to (3) must be repeated until all payoffs are calculated.

Now press 1 to start the program. If you make a mistake entering a value, you can use the delete key and try again.

CHAPTER 5

Probabilities

5.1 Adding up the Odds

Each chance node on the tree heralds a series of possible OUTCOMES, with each outcome having a particular likelihood or "probability" of occuring. For instance, if we decide not to wear a raincoat, the chance outcomes are that it will or will not rain. If we felt that it was certainly going to rain, we could express this by saying that there is a 100% chance of rain. – 100% represents certainty. On the other hand, we may decide that there is a 90% chance that it will rain, and a 10% chance that it will not rain.

If we once again reduce our forecast of rain to a 60% chance, then, of course, we are also implying that the chance that it will not rain increases from 10% to 40%. What we are saying here is that the total of the probabilities of all the outcomes must add up to 100%. If the probabilities do not add up to 100% than either the probabilities are wrong, or we have not included all the possible outcomes. When we draw a chance node on a decision tree, the probabilites of the events leading from it MUST add up to 100% because ALL possible outcomes must be included.

Using the rainy day example again, we could list the following possibilities:

1) It will only rain when I am on my way to work – chance of 10%

2) It will only rain when I am on my way home – chance of 20%

3) It will not rain at all today – chance of 10%

So far, this list of outcomes could be correct, but the probabilities do not add up to 100% because there are some other possible outcomes:

4) It will rain on my way to work AND on my way home – chance of 30%

5) It will rain, but not when I am travelling to or from work – chance of 30%

Now they add up to 100%, so there cannot be any more possible outcomes. For instance, we could feel that there was a 5% chance that it would be raining at 3.00pm, when I am still at work. This cannot be an extra possible outcome because we already have probabilities adding up to 100%. In fact, if we look at the list, we can see that this possibility is already covered by alternative 5, and therefore need not be added.

It is possible to simplify the range of outcomes by combining them and

adding their probabilities together. In the raincoat example, I am only concerned with whether or not it will rain when I am outside, that is, when I am on my way to or from work. So we can add all the outcomes where it does rain when I am out and all the outcomes where it doesn't, thus reducing the problem to only two outcomes as follows:

Take 1) Rains on my way to work – chance of 10%
2) Rains on my way home – chance of 20%
and 4) Rains in both directions – chance of 30%

add these together to get:

Rains when I am going to or from work – chance of 60%

Similarly:

3) Doesn't rain at all – chance of 10%
and 5) Rains, but not when I am out – chance of 30%

add together to get:

No rain when I am going to or from work – chance of 40%

Both ways of considering the outcomes are correct; whether there are five or more outcomes, or only two, as long as they add up to 100%. The important thing is to divide up the outcomes in a way which is relevant to your problem.

5.2 Probabilities & Percentages

Up to this stage, we have discussed probabilities in terms of percentages, because most people think of them in this way in day to day life. However, there is a mathematical convention that probabilities are expressed as numbers in the range 0 to 1. An event with a probability of 0 has no chance of occurring, whilst an event with a probability of 1 is certain to occur. The method for changing from percentage values to decimal values is simple; just write the percentage value after a decimal point, remembering to put a zero in front of percentages less than 10. e.g. 70% becomes 0.70, which is the same as 0.7, because zeros on the end of decimals have no effect; and 7% is changed to 07% and becomes 0.07.

Let us return to the computer agency problem and insert the probabilities; We have done some homework on the risks involved, and we have reached some conclusions. We think that the Avocado will be a popular model, and we feel that there is a 60% chance (probability of 0.6)

of selling it by the deadline. Obviously, on the other hand, there is a 40% chance (probability of 0.4) of not selling it, and you will have to give it back. The Banana, on the other hand, is a much more expensive unit, so there is only a 20% chance (probability of 0.2) of selling it in time. What does that make the probability of NOT selling it?

Press P R to restart the computer. Follow the instructions on the screen to select each outcome in turn, and enter its probability.

TO CONVERT PERCENTAGES TO PROBABILITIES:

1. A decimal probability is like a percentage with a decimal point in front of it.

   e.g.: 65% = .65, 32% = .32, and so on.

BUT

2. For small percentages less than 10%, add a zero in front first.

   e.g.: 6% = 06% = .06, 3% = 03% = .03, and so on.

3. For decimal percentages, just ignore the old decimal point.

   e.g.: 38.5% = .385, 94.67% = .9467, 3.25% = 03.25% = .0325.

CHAPTER 6
Expected Value

6.1 The Key Concept

Understanding the idea of "Expected Value" is critical to the constructive use of Decision Analysis techniques. We can define the Expected Value of a situation as the average value it would have if it were to be repeated many times. In most situations, values in decision making are expressed in monetary terms, and so are called "Expected Monetary Values" or EMV for short.

6.2 EMV of Chance Events

Let us consider an example:

> A novice card sharp has a normal pack of 52 cards – no Jokers in it. He is going to offer you a proposal; You cut the pack 100 times. Every time you get a black card, he pays you £10, but every time you draw a red card, you have to pay him £6. Do you accept his offer?

Well, I think you can tell that this is a good game from your point of view. Half of the cards are black, and half are red, so you can expect to draw about 50 of each. You will win 50 × £10, and have to pay 50 × £6, and you don't need a computer to work out that you will then make a profit of about £200.

The Expected Monetary Value of this game is therefore £200. Now we can work out the EMV of only one cut by dividing the overall EMV by the number of cuts in the game, 100. So the EMV of one cut is £200/100 = £2. On average, you will earn £2 from each cut. This is the same as saying you have a 50% chance of winning £10 and a 50% chance of losing £6 for each cut:

$$\pounds 10 \times 50\% \text{ plus } -\pounds 6 \times 50\%$$

which is the same as:

$$\pounds 10 \times 50\% \text{ minus } \pounds 6 \times 50\%$$

$$= \pounds 5 \text{ minus } \pounds 3 = \pounds 2$$

To calculate the EMV of a chance event, simply multiply the value of each outcome by its probability and then add them together. Don't forget that, as in our example, some values are negative (we usually call negative values COSTS) and if they are, they must be subtracted instead.

This concept can be transferred to the Decision Tree as follows: the EMV of a chance node is calculated by multiplying the EMV of each of the nodes immediately following by the probability of it occuring, and adding the results together.

6.3 EMV of Decisions

Now, I am afraid that our novice card sharp has been listening in to our discussion, and has figured out that his proposal is not such a good idea from his point of view, so he has changed it:

> What he now offers is this; he will lay a black card and a red card face up on the table and ask you to choose one of the cards. He tells you that if you choose a red card, he will pay you £6, but if you choose a black card, you must pay him £10. He reckons that there is a 50% chance that you will pick either card, so on average he will win £2! Can you see the obvious flaw in his devious plan?

Well, you and I know that we will not leave our selection to chance, you will pick the red card every time, and he will have to pay you £6 every time. The difference is that this is not a chance node, but a decision node. You can decide what will happen. The EMV is £6 because you will always choose to take the higher payoff.

Hence, the EMV of a decision is the highest of the values of the alternatives available. Again, this approach can be transferred to the Decision Tree; the EMV of a decision node is selected as the highest of the EMVs of the immediately following nodes. The decision actions leading to nodes with lower EMVs are permanently discarded.

TO CALCULATE THE EMV OF A NODE:

THE EMV of a CHANCE node is the total of the EMVs of all the nodes which follow it, each multiplied by the probability on the branch which leads to it.

THE EMV of a DECISION node is the highest of the EMVs of the nodes which follow it.

THE EMV of a TERMINAL node is the same as its PAYOFF.

Finally, return to the computer and press E V and follow the instructions to run through some exercises on calculating the EMV of chance and decision nodes. The computer will generate a series of at least fifteen exercises, starting with simple ones and getting more difficult as you go. There will be a mixture of decision and chance nodes to solve. Decision nodes just require you to choose a single value, but a calculation is required for a chance node. If a calculation is needed, you just have to supply the figures, and the computer does the arithmetic for you. Remember that on a computer keyboard, you use the * symbol to multiply.

CHAPTER 7

The Roll-Back

7.1 Applying EMV

Whilst EMV is the key concept in the use of Decision Analysis, the actual technique which produces the answer is called the "Roll-back". The name comes from the way we start at the end of the tree and work backwards through it to get to the answer. Simply start at the ends of the tree and work out the expected value of each node in turn until, finally, we have the EMV of the very first decision node. Then you have your answer; the first decision you make is the one with the highest EMV. After that, you follow your progress through the tree and continue by making each subsequent decision by selecting the highest EMV.

Now that you know from the last section how to calculate EMVs, you can go straight on and "Roll Back" your first tree. You can see why we must start at the end and work backwards; because the EMV of a node depends upon the EMVs of the following nodes, we have to calculate them first.

We will now use the original Used Car example as the first exercise. Press R B to restart the computer, and begin to work through it. As in the previous chapter, you don't need to do the calculation in full for the chance nodes – just enter your workings, such as "1000*0.3 – 200*0.7".

7.2 Another Review Problem

It is a very straightforward procedure – just try rolling back one more tree. We'll use the Computer Agency example this time. Press 1 when you are ready.

THE STEPS SO FAR

1. Draw a diagram of the sequence of decisions and chance events which form the problem.
2. Calculate the payoff for each of the terminated branches.
3. Decide what the probabilities are for all of the chance outcomes.
4. Working from the ends back to the beginning, calculate the EMV of every node on the tree.
5. Choose the decisions which lead to the highest EMV nodes.

Congratulations. You have now acquired the basic skills required to construct a decision tree. Move on to the next chapter, and we will present some more advanced techniques. Although before you continue, you may want to try a few problems on the Applications Program.

CHAPTER 8

Risk Profile

8.1 Review the Possibilities

The trouble with Decision Analysis is that you cannot be certain what the final outcome of your first decision will be (if you could be, then you wouldn't need to use decision analysis in the first place!). Even when you know which decision to take initially, there is still more than one possible outcome.

The greatest weakness of using Decision Trees to analyse a complex problem occurs because many people fail to take the next two steps – analysing risk, and measuring sensitivity. This is because they can represent a significant chore, once so much time has been spent achieving the first Roll-Back of the tree. Fortunately, when you have completed this learning process, you will be able to use the Applications Program to undertake these crucial steps with ease. But first, back to the method:

Consider the Used Car example; when you have eliminated the lower value alternatives, there are three possible final outcomes:

1) The cheap car doesn't break down, and all is well, costing you £600.
   or
2) The car breaks down, you sell it at a loss and buy the guaranteed car, costing you £1200 altogether.
   or
3) The car breaks down, you sell it at a profit and buy the guaranteed car, costing you a final figure of £800.

So, we can say that there is some risk that our decision will cost us as little as £600, or as much as £1200. Suppose that you don't have £1200, but only £1000, then this risk may not be a very pleasant prospect. If you cannot afford to take the risk, you may have to choose another option with a poorer EMV, with no risk of it costing more than £1000. In the Used Car case, this would mean buying the guaranteed car. On the other hand, if you can afford to take the risk, then it is more likely that you would be better off with the cheap car.

This is what checking the Risk Profile of the Decision means, and it is an important step which you must always take in using decision analysis, to be certain that there are no hidden risks which you would be unhappy to accept.

8.2 Measure the Risk

We can actually go a little further than this and work out how likely each possible outcome is once we have selected the best sequence of

decisions. Just follow these simple steps:

1) Look through your tree very carefully and write down all the possible final outcomes which remain after you have selected the best decisions.
2) For the first possible outcome, trace the path back to the starting decision node. Write down the probability on each of the chance outcomes which lie on that path.
3) Multiply all the probabilities together. The answer you get is the probability of that final outcome occurring
4) Repeat steps 2 and 3 for all the other possible outcomes.
5) As a double check, just add all the calculated probabilities of final outcomes together. If you have worked through correctly, they will add to 1 because they represent the sum of all possible outcomes.

Press **R P** on the keyboard, and the computer will demonstrate how to apply this to the used car example.

8.3 Final Check

We can summarize the risks of buying the cheap car as follows:
1) 0.3 probability that it doesn't break down, and all is well, costing you £600.
2) 0.28 probability that it breaks down, you sell it at a loss and buy the guaranteed car, costing you £1200 altogether.
3) 0.42 probability that it breaks down, you sell it at a profit and buy the guaranteed car, costing you a total of £800.

As a final check, make sure that the probabilities add up to 1:

$$0.3 + 0.28 + 0.42 = 1.0.$$

Now press 1 and try out the process on the computer agency decision. Use the highlight to select each possible final outcome, then press the space bar and feed in the percentages which lie on the path of that outcome.

CHAPTER 9

Sensitivity

9.1 Change the Numbers

The great advantage of using a tree to solve a decision problem is that it forces you to structure your view of the problem. But what you must not lose sight of is the fact that the solution which the tree provides is only as good as the data YOU feed in. Don't be fooled by your own numbers just because you have processed them in a sophisticated way.

Often you will find that the difference in EMVs between two alternative decisions is only a small figure. In those cases, it is essential that you manipulate the numbers to find out how much they need to be changed to alter the decision. This is an easy task when you are using the Applications Program supplied in this package, but it can be very tiresome if you are solving the tree manually. The process of changing the numbers to see what happens is called a "Sensitivity Analysis" because you are finding out how sensitive the solution is to the data you have provided.

To demonstrate this point, press S Y to redisplay the used car tree. Let us now try changing some of the values. The computer will allow you to select any probability or payoff, and permit you to change it within a reasonable range. Each change will recalculate the entire tree. You can watch the effect as it happens.

Find out which value can be changed the least amount to change the initial decision from the cheap car to the good car. You can also select the two options at the top left of the screen. "Finish Exercise" is self explanatory. The "Restore Values" alternative will change all of the figures back to their original figures – very useful if you want to test one factor at a time.

ALWAYS CALCULATE THE RISK PROFILE

Remember the steps involved:

1. When the tree has been rolled back, eliminate all of the payoffs which will never be selected.
2. For each of the remaining payoffs, trace along the sequence of events, which leads to it, and list the probabilities encountered.
3. Multiply this sequence of probabilities together for each payoff, and this is the probability of that payoff occurring.

9.2 Applying Judgement

The second point to bear in mind when considering a solution which depends on only a very small difference between EMVs is the non quantifiable or non financial component of the decision. Suppose you are using the tree to decide whether to close down say Microfruit PLC. You have input all the numbers, including profits, losses, redundancy pay, and so on, and the tree says "CLOSE DOWN" because that has an EMV of £2,000,000, compared with £1,990,000 if you stay open. When you consider the social and public relations effects of firing the workforce of 500 people, you may think that this outweighs the small difference in EMVs.

In summary:

- Always check the sensitivity of the answer to changes in the data.
- Always consider the qualitative issues.
- Always produce a risk profile.

and, most important of all:

- Always interpret the answer using common sense.

CHAPTER 10

Value of Information

10.1 A Typical Problem

When you are working through a complex decision model, you will often find yourself wishing that you had some more information to help you make your decision. One thing that you can work out from the tree is how much some extra information might be worth, in terms of an increase in the value of the decision. An example will probably make this point clearer:

> Suppose that you have the opportunity to buy 1000 Microfruit shares. You know that they are introducing a new portable computer, the Currant, but that it may be running behind schedule. The Microfruit watchers say that there is a 70% chance that the new computer will be late. If it is late, the shares will fall from £2.30 to £1.50, but if it is on time, they will rise to £6.00.

Press VI to draw this simple tree.

As you can see, the "buy" option has a positive EMV of £550, so, providing you can live with the risk of losing £800, you should go ahead.

10.2 Perfect Information

Just before you go and see your broker, you meet a Microfruit technician in the pub who knows whether or not the Currant is going to be late. He is willing to advise you providing you can agree a fee for his knowledge. How much is this information worth?

Well, there is a 70% chance that he will tell you that the Currant is late, in which case you will not make the investment and you will win or lose nothing. On the other hand, there is a 30% chance that he will tell you that it is on time and in that case you will rush around to your brokers immediately, knowing that you will make a profit of £3700. So, his information will change the EMV to 0.7 times zero plus 0.3 times £3700, which is £1110, £560 more than without the information. Therefore, providing the information costs less than £560, you will be better off if you buy it. This is because the information eliminates the risk of losing any money.

The increase in EMV brought about by knowing what is going to happen is called the Expected Value of Perfect Information (EVPI for short). You must remember, however, that finding someone who knows what is going to happen does not change the probabilities of the event. The technician does not change the chance that the Currant will be late, it is just that from his point of view, the event has already happened.

10.3 Sample Information

Now the chances of being able to buy perfect information are very slight, but there are often ways of obtaining some better information at a price. For instance, perhaps you know of a Microfruit analyst who has a reputation for making much better predictions than most of the others, and who sells his services for a fee. You now have the option of securing his services before you make up your mind. Therefore we can now incorporate this additional decision into the tree. Press 1

Doesn't one extra step make a big difference to the size of the tree? Now we have some extra chance nodes and outcomes, and so we need some more probabilities. The only extra information we have is that the analyst has an 80% success rate with his predictions, and we must combine this with our previous information that there is a 70% chance of the Currant being late. Here we require a particularly fancy bit of arithmetic based upon a concept known as "Bayes Theorem". Watch carefully.

What we need to know first is the chance that the analyst's advice will be "It's Late", and the chance that it will be "It's on Time". The best way to work this out is on a diagram, so press 2 and the computer will act as our drawing board. First, we have drawn a box to represent the "future". We can divide it vertically to represent the chance of Currant being late, and the chance of it being on time. Remember that the proportions are 0.7 to 0.3 – press 3. Now we can divide it horizontally for the chances of the analyst being right and wrong in the proportions 0.8 to 0.2 – press 4. Next, we consider what each part of the box represents:

1) The top left hand section represents the analyst being right in his forecast and the Currant being late, so this occurs when the analyst says that the Currant will be LATE and it is.

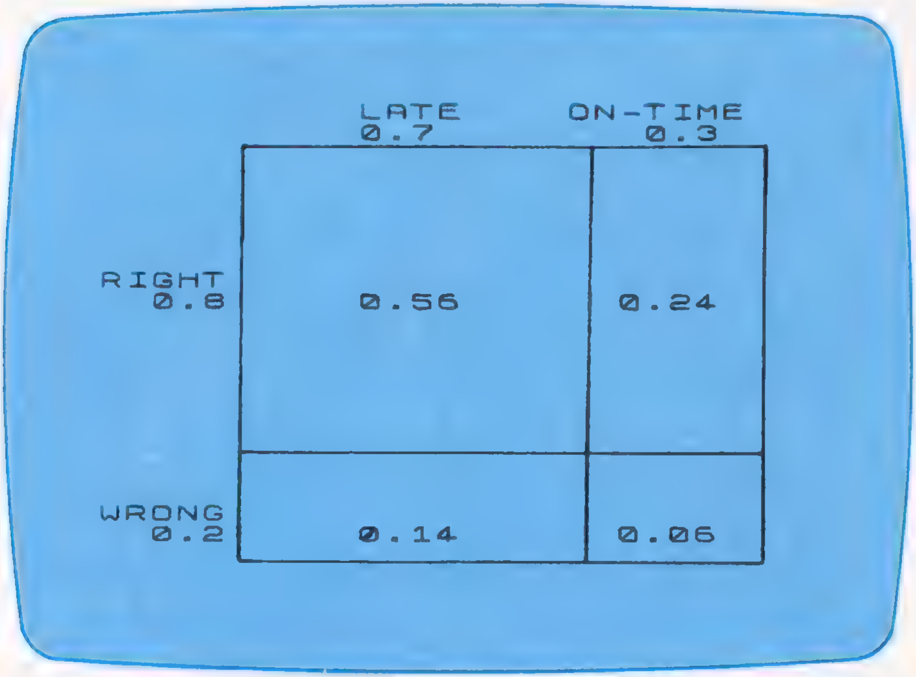
2) Top right is analyst correct and Currant on time, so the analyst must correctly predict that the Currant will be ON TIME.

3) The bottom left signifies analyst wrong and Currant late, so this occurs when the analyst says that the Currant is ON TIME when in fact it is not.

4) Likewise, bottom right is analyst wrong and Currant on time, so in this case, the analyst must say that the Currant is LATE when it is not.

The area of each part of the box is proportional to the chance that the event it represents will occur. It can be calculated just as in geometry by multiplying it's width by it's depth. For instance, the chance of the analyst

being right and the Currant being on time is 0.8 times 0.7, which is 0.56. You can watch the computer do all the sums by pressing 5.



Now, for the tree we need to know the chance of the analyst saying that Currant will be on time and the chance that he will say it will be late. That's easy – just add the appropriate probabilities together:

A) He says "ON TIME" 0.14 (bottom left) plus 0.24 (top right), total 0.38.

B) He says "LATE" 0.56 (top left) plus 0.06 (bottom right), total 0.62.

Go back to the tree by pressing 6 and we will add these probabilities. Remember that we asked the analyst whether the Currant will be late. Thus, "Yes" means that he says that it will be late, and "No" that it will be on time.

If you trace the path along the bottom of the screen, the next chance node you reach is the point where we see whether the shares rise or fall (i.e. whether the Currant is on time or late), following the analyst's forecast that the Currant will be late. After that forecast, what are the chances that he is right or wrong? From the box diagram, we know that

our estimate of his "LATE" forecast was based on him saying "LATE" and being right (0.56), plus him saying "LATE" and being wrong (0.06), totalling 0.62. Now we just need to convert the two parts into proportions of the total, 0.62, as follows:

$$0.56 \text{ becomes } \frac{0.56}{0.62} = 0.9$$

$$0.06 \text{ becomes } \frac{0.06}{0.62} = 0.1$$

(These figures are rounded up, because there is no point in being any more accurate in this type of decision tree)

Therefore, once he has forecast that the Currant will be "LATE", the analyst has a 0.9 probability of being right and 0.1 probability of being wrong. – Press 7 to enter these figures on the tree.

Similarly for the analyst's "ON TIME" forecast, we perform the same calculations:

Analyst correct:

$$0.24 \text{ becomes } \frac{0.24}{0.38} = 0.63$$

Analyst wrong:

$$0.14 \text{ becomes } \frac{0.14}{0.38} = 0.37$$

– and enter them on the tree by pressing 8. Finally, we need to insert the payoffs for the extra branches. – Press 9 to do that. As you can see, the payoffs are no different from those we used on the very first Rise and Fall branches of the tree. The computer is now waiting for you to "roll back" the tree, just as you learned to do in section 2.6. Off you go.

Now, look what's happened! The EMV has risen from £550 to £773, and so the analyst's advice is worth something to us – the difference between £550 and £773, £223. Therefore, if we can buy his advice for less than £223, we should take it! That figure is called the Expected Value of Sample Information, or EVSI for short, and should not be confused with EVPI which we reviewed earlier. – Remember that the EVPI was much higher at £560 in this case.

The more accurate the sample information becomes, the closer EVSI gets to EVPI, but it will never get larger than EVPI. This is a useful point to remember because, as you can see from the work we have done, EVPI is much easier to calculate than EVSI. If you know how much the information is going to cost you, always work out the EVPI first to make sure that the cost is less than that figure, before you begin the lengthy process of calculating EVSI.

10.4 Summary

Remember the difference between EVPI and EVSI:

EVPI, *Expected Value of Perfect Information* is the increase in EMV that can be achieved if you can get a 100% forecast of what the outcome of a chance event will be.
EVSI, *Expected Value of Sample Information* is the increase in EMV that can be achieved if you can use an experiment, sample or expert to gain a more accurate forecast of what the outcome of a chance event might be.

To make sure that you can handle EVSI, here are some revision exercises based upon the Microfruit Share example, but with the percentages changed. You can run as many or as few of these exercises as you wish. Just press 0 to start.

CALCULATING EVSI

1. Draw the simple decision tree without showing the option of obtaining additional information, and perform the Roll-Back.
2. Add the new option of seeking the additional information.
3. Make an assessment of the reliability of the extra information.
4. Use the probability box to calculate the probabilities to add to the tree.
5. Roll-Back the tree in the usual way, and the change in the EMV of the initial node is the EVSI.

CHAPTER 11

More Practice

Finally, before you attempt to apply **Decision Maker** to your own problems, it would be wise to run through a few sample problems just to check your skill. We have two series of problems for you. The first set is a series of Roll-Back exercises in which the computer will generate trees with payoffs and probabilities marked in. You can do as many as you like, and the computer will always give you a hand if you get stuck.

The second series of problems consists of two decision case studies. You will find them set out in Appendix 1, sections A1.4 and A1.5. You will need to use the Applications Program to work out the solutions for yourself, and this will mean reading through Chapter 12 to familiarize yourself with it. When you are satisfied with your results, you should save your trees, and load our answers into the Applications Program to see how we handled the problems – they are filed with the Applications Program. Good luck, and press M P to proceed with the first series of exercises.

CHAPTER 12

Applications

12.1 Starting the Program

Load the Applications Program in accordance with the instructions for your type of computer. You will find some suggestions in Appendix 2. When the program has been loaded, the menu of initial options will be displayed:

Start a New Tree
Load a Previous Tree
Terminate this Program

You will see that the first option on the menu has been highlighted on the screen. This means that if you press the RETURN (or ENTER) key, it will perform this operation. If that is not your preferred choice, pressing SPACE will move the highlight down the list. Use this feature to make your selection, and then press RETURN (or ENTER). There is no problem is you go past your choice, because the highlight will return to the top of the menu once it has reached the bottom. Try rolling through the list a few times before you make your decision.

The **Terminate** option will rarely be required and you will only be able to load a previous tree if you have already used the program to create one, or if you want to review one of the sample trees included in this package (refer to Appendix 1). Therefore, you will probably go straight to **Start a New Tree**. If you want to load a tree, then you should refer to section 12.7, "File Handling".

12.2 Constructing a Tree

We suggest that before you start to build a tree on the computer, you should attempt to define its basic structure on paper. Don't worry too much about the details, as long as the overall form is clear in your mind before you start.

When you select **Start a New Tree**, the screen will clear, and the very first decision node will be drawn at the left hand side. At the top you will see the display **Prior Event; Starting Decision.** On subsequent screens, the function of this line will become clearer, but initially, it simply acts as a reminder that this is the very first node of the tree.

At the bottom of the screen there is a message requesting you to enter the number of different actions to be initiated at this node. The number is limited to five by the size of the screen, and this should be ample in most circumstances. If it is not sufficient, then refer to section 12.8, "Further Manipulation" for advice. When you have entered the number, the computer will draw the first branch of the tree and ask for details, a

description, a cost or value, and the type of node to which the branch leads. You do not have to enter anything for the first two questions – just press RETURN, but a node type must always be given. Do not worry about any mistakes you make as you go because there is an editing feature available once the screen is complete.

The questions are repeated for each of the branches in turn, with the flashing "?" showing where the input will be written. When all branches are defined, a menu will appear in the bottom left hand corner of the screen. This operates in the same way as the first menu you used; that is the SPACE bar moves the highlight and RETURN selects your preference. All menu items which appear during operation have been shortened to no more than five letters so that they never interfere with the screen display, but the meaning of each will become clearer when you have used them once or twice. The first menu contains four options:

Go On – The computer will move straight on to the next node, seeking the information required to complete the tree; see below.

Alter – Calls the edit routine so that you can change anything which you have defined on the screen. Refer to section 12.3, "Editing as you go".

Whole – Displays an outline picture of the entire tree. Refer to section 12.4, "Tree Display".

Copy – If you have a printer, this instruction will print a copy of whatever is on the screen before returning you to the program.

The **Go On** option will clear the screen and select a chance or decision node for which the outcomes or actions have not yet been defined. You will be able to identify which one it is by the description of the prior event at the top of the screen, i.e., the description of the event branch which leads to the left hand node. The computer will ask you the same series of questions which it asked on the first screen, but if the new left hand node is a chance node, then it will also ask for the probability of each outcome. These probabilities must add up to 1, or the computer will ask you to change them until they do.

On completion of the questions, the option menu will appear once again. This procedure can be repeated until all nodes are defined and all remaining branches end in terminal nodes. When this has happened, selection of the **Go On** option will cause the computer to calculate the EMV of the tree and return you to the main menu.

12.3 Editing as You Go

If you select the **Alter** option on the menu at any time, it will display another menu of available actions:

Other – Takes you back to the Go On/Alter/Whole menu.
Edit – There is one edit line for each branch on the screen. Selecting any one will call the full edit menu and apply it to that particular line. e.g. **Edit2** will enable you to edit the 2nd line from the top of the screen.
Add – This will only appear if there are less than five branches. If you select it, the screen will be redrawn with an extra branch, and you will be asked for the additional data required. If it is a chance node, you will have to use **Edit** to balance the other probabilities, otherwise the computer will force you to re-enter them for all of the branches from that node.

The full edit menu will appear as follows when any one of the **Edit** lines is selected:

Other – Takes you back to the previous menu. If you do not want to edit the current "active" line (displayed at the bottom of the screen), use this option to go back to the previous menu to select another line.
Label – Allows you to re-enter the description of the branch.
Value – To re-enter the cost or value.
Prob – To re-enter the probability.
Node – To change the type of node to which the branch leads.
Erase – To delete the branch altogether. If it is a chance node, the probabilities of the other outcomes will have to be re-entered. Select the relevant lines to edit these probabilities, or the computer will force you to alter them when you attempt to continue.

Note that if you change a node type or delete a branch, any following nodes and branches will also be deleted. This will not concern you if you are building the tree for the first time, but if you have completed it, and you are using the edit routines to make changes, be very careful of this point.

If you have completed editing one branch and you want to edit another, use **Other** to go back to the previous menu and choose another branch number. When you have finished completely, use **Other** and **Other** again to get back to the **Go On/Alter/Whole** menu.

12.4 Tree Display

On completion of a screen of inputs, the menu will include the option **Whole**. This will draw for you an outline diagram of the part of the decision tree which you have entered up to this point. The screen will include three features:

The Tree Diagram Itself
A Cursor
An Option Menu

The diagram itself is a straightforward representation of the tree, with the three different types of node: decision, chance and terminal, distinguishable from one another.

The cursor is made up of a pair of arrows which point out a particular node. When the display is first drawn, this cursor is located on the left hand node of the screen which you have just left, so you can see where on the tree you have been working. If you have not yet identified the cursor, the simplest way to see it is to move it around the screen. Use the arrow keys on the keyboard to do this. Note that it does not move continuously but jumps from one point to another. These points form the grid of locations on the screen at which a node could occur at some time. The cursor position is used in conjunction with some of the menu options to control the operation of the program.

The exact list of options included in the menu varies, depending upon the current status of the decision tree. Here is a list of all which could appear:

Other – This will take you on to a secondary menu consisting of:

- **Go On** – As on the other menus, this instructs the computer to continue seeking information to complete the tree. If it is already complete, then it will calculate the EMV and return to the main menu.
- **Whole** – Again, as on the other menus, this displays an outline picture of the whole tree. Although you already have a tree displayed on the screen, you may need this option to get back to the main tree if you have used **Sub/T**.
- **Copy** – as before, this will send a copy of the present screen to the printer.

Query – The computer will display all of the details of the location marked on the tree by the cursor. Specifically, it will give the EMV of the node itself if it has been calculated, together with the description, value and probability of the branch to the left of the node.

Store – The program features a memory facility which can be used to save all or part of the tree. This option instructs the computer to save in memory all of the tree to the right of and including the node marked by the cursor.

Clear – This option clears the memory so that another part of the tree can be saved instead.

Chain – A copy of the contents of the store will be attached to the tree at the cursor position. The cursor must be at a terminal node, or a chance or decision node which has not been defined. Whatever the type of node at the cursor, it will be changed to that of the first node in memory. When **Chain** has been used, it will always be followed by the same secondary menu which is called by **Other**. Then you can decide whether to **Go On** or **Whole**, as you require.

Study – The cursor node, and its own branches will be displayed in full on the screen, together with the menu described in 4.3, "Editing as you go". This is the method used to alter the parts of the tree which have already been defined.

Sub/T – Sometimes, the tree becomes so large or complex that it cannot all be displayed at once. In this situation, you are warned by the computer which displays the number of hidden sub trees alongside this menu option. The location of the missing parts of tree will be at chance or decision nodes on the screen which do not have any branches showing. Simply move the cursor to one of these locations, and call the **Sub/T** display option. That part of the tree to the right of the cursor will then be displayed separately. **Sub/T** is always available, so that even if the whole tree is visible, you can choose to display only part of the tree if you wish. When a sub tree is displayed, a warning **Sub tree** is displayed at the top left hand corner of the screen.

If at any time you press **Go On** and are presented with a node to define which you do not recognise, enter **0** for the number of branches, and the computer will display a menu featuring the **Whole** option. You can then call up a view of the entire tree to identify the node in question.

12.5 Finding the Solution

When the tree has been fully defined, selecting **Go On** from any menu will cause the computer to calculate the EMV of the tree and return you to the main menu. The EMV will be displayed at the bottom of the screen, and the following alternatives will be available:

Start a New Tree
Load a Previous Tree
Display Initial Decision Node and Review
Calculate the Risk Profile
Save this Tree
Terminate this Program

The load and save routines are discussed in section 12.7, and the first and last options are quite clear. The remaining two alternatives are the ones to use to study the solution. **Display Initial Decision Node and Review** redisplays the initial decision node screen, and the **Go On/Alter/Whole/Copy** menu. The key difference to notice is that once the EMV has been calculated, the screen will show "bars" on the rejected decision options, and the EMV of the left hand node will be displayed. Thus, the selected initial decision will be clearly defined. If you wish to study the various paths through the tree, simply select the **Whole** option to draw the whole tree and use the cursor and **Query** command to review the information at all the nodes.

You can look at each node in detail, if you wish, by selecting **Study**, and, when you are ready, you can return to the main menu with the **Go On** option. If you choose to make alterations to the tree, you can do so with the **Study** and **Chain** instructions, but in that case, **Go On** will only return you to the main menu if the tree is fully defined, and the computer will recalculate the EMV as well.

Once back at the main menu, you can select **Calculate the Risk Profile**. The probabilities and payoffs of all the possible outcomes will then be displayed. You can then return to the main menu or copy the risk profile to a printer, if you have one.

12.6 Value of Sample Information

Finally, one further piece of information can be obtained from the tree. Use the options already mentioned to return to the display of the entire tree. If you now move the cursor to any chance node and select **Study**, the node will be displayed in detail as usual. Providing the EMV has been calculated, an additional option will appear on the menu; **EVSI**. Selecting

this will calculate the value of sample information for that chance event. The computer will ask you two questions:

Reliability of the sample? – enter the estimated reliability as a number between 0 and 1. A value of 1 represents perfect information and thus will give EVPI.

Value of the zero option? – what is the cost or value of avoiding this risk? i.e., if an outcome with a negative EMV is predicted, how much will it cost to do something else or nothing instead? Typically, this can be set at zero.

The EVSI will then be calculated and displayed at the bottom of the screen. Selecting **EVSI** again will allow a recalculation with other values or alternatively, you can continue your inspection of the tree by using **Other**.

12.7 File Handling

When you have a fully defined tree, the **Go On** option will return you to the main menu, and there you will find the option of saving the tree. If this is selected, the computer will ask for a name for the tree, and will then start the **SAVE** operation. The exact details of this operation will vary from one computer type to another, so follow the instructions on the screen very carefully. When the tree file has been saved, keep a record of the name used so that you can recall it when required.

Loading the tree from tape is simply the reverse procedure. Select the appropriate menu option, and follow the instructions on the computer screen.

12.8 Further Manipulation

Now that you have read through an explanation of all the facilities provided by this program, here are a few ideas on maximising its effectiveness.

One important component of the decision analysis process is sensitivity analysis; that is, testing how sensitive the decisions are to incremental adjustments to various assumptions – particularly the costs, values and probabilities. The computer allows you to input your best guesses first, and then go back into the tree to change each of the variables in turn to see which makes the greatest impact on the outcome.

There are basically only two constraints in the program, you cannot have more than 150 nodes, and each decision or chance node cannot have more than five branches. If you actually come up against either of these constraints, then you should first ask yourself whether you are making

things too complicated. If you are convinced that your approach is correct, then here is what you must do:

— More Than 150 Nodes:

Break the tree down into two or more sub trees each of less than 150 nodes and solve them separately.

— More Than 5 Branches:

Introduce a "dummy" node. Put 4 of the branches on the original node and run a fifth branch to the dummy node. Put the remaining branches onto the dummy. Each dummy will provide up to 5 additional branches – just use as many as you like, but take care with the probabilities on chance nodes, because they must add up to 1 at each node and preserve the desired overall probabilities.

Finally, some clues on major re-editing. The key feature here is the memory facility. Often a tree will have the same sub tree at a number of different points. So, first define it once, and then save it in memory. It can then be linked on wherever it is required. Don't forget, however, that you may need to use the edit routines to change the specific values on the sub tree in different positions. Once a particular sub tree has been stored, it can be chained as many times as you wish without resaving.

The other important use of memory occurs when you want to insert some extra steps into the middle of the tree, or delete some intermediate steps. Simply store the end of the tree in memory, and then edit the main tree as required and link the end back into place.

POSTSCRIPT

Decision Criteria

The analysis of risk, shown in Chapter 8, gives rise to consideration of whether the approach of using EMV is appropriate in every case. Expected Value is the most popular criterion and it is the one incorporated into the Applications Program, but it does carry the problem that a large negative outcome with a very low probability may be hiding in the result. That is why Chapter 8 emphasises that you must perform a risk analysis on the solution you reach.

One alternative, and very much more conservative criterion which can be applied is known as MAXIMIN. In this approach, the aim is to choose the decision in which the worst possible outcome is the lowest. In our Used Car example, we would choose the guaranteed car, because the worst outcome is a cost of £1000, compared with the possible cost of £1200 for the cheap car. In the Microfruit Dealer case, we would choose not to proceed at all because both of the other alternatives harbour a risk of losing some money. You can use maximin as a criterion if you wish, but in many cases, it will eliminate potentially profitable moves because of a small risk of loss.

APPENDIX 1

Sample Decision Problems

A1.1 The Used Car Purchase

You are going to buy a five year old Ford Escort, either from the local garage for £1000, or from a private seller for £600. The first is fully guaranteed, whilst the second is not. There is a 70% chance that the cheaper car will break down and, if it does, you can sell it or repair it. Repairs may cost £1000 (40% chance) or £300 (60% chance). If you sell it, you will get £800 (60% chance) or £400 (40% chance), but if you do sell, you will have to go straight to the garage to buy the other (£1000) car, because you need the transport.

A1.2 The Microfruit Dealer

You are setting up a new computer showroom. One of the computer manufacturers, Microfruit PLC, has offered you the opportunity to obtain an agency for their range of two computers, the Avocado and the Banana. (We'll call them A and B). You can choose to accept one type A or one type B computer only. If you sell it within a certain time limit, they will offer you one of the other type to sell, but if you fail they will take the computer back and refuse to deal with you any more. On the other hand, if you sell the second one as well, they will appoint you as a dealer. You have calculated the costs involved as follows:

Cost of advertising the Avocado	£ 400
Cost of advertising the Banana	£ 500
Profit from selling the Avocado	£ 200
Profit from selling the Banana	£1000
Net Profit from getting a dealership	£5000

We think that the Avocado will be a popular model, and that there is a 60% chance of selling it by the deadline. The Banana, on the other hand, is a much more expensive unit, and so there is only a 20% chance of selling it in time.

A1.3 The Microfruit Shares

You have the opportunity to buy 1000 Microfruit shares. You know that they are introducing a new portable computer, the Currant, but that it may be running behind schedule. The Microfruit watchers say that there is a 70% chance that the new computer will be late. If it is late, the shares will fall from £2.30 to £1.50, but if it is on time, they will rise to £6.00.

A1.4 The Swedish Deal

Jim Douglas has the opportunity to close a small deal in Sweden, which will require him to fly over to Stockholm in person. He is expecting a call in the next two weeks which will give him three days notice of the date of the meeting. He has to fabricate a squinge valve to take with him, and this will cost £200 and take 1 day to make. If he wins the deal, he will be able to sell the valve for £800, otherwise it will be valueless.

He can fly there in a regular flight for a return fare of £400 which his travel agent can guarantee to book on any day. Alternatively, he can try to get on the daily standby flight which will only cost £120 return, but there is only a 60% chance of a seat. If he gets to Stockholm with a full day to spare, he will be able to prepare an elaborate presentation, and will stand an 80% chance of winning the deal. If, on the other hand, he arrives just in time, the chances falls to 60%. Finally, if he is late, the deal is off.

A1.5 The Charity Concert

The Club has decided to hold a charity concert. If they provide a £50 non refundable deposit immediately, they can book a hall which seats 600, otherwise they will have to hold an outdoor concert in the Park. The latter option has the advantage of being able to accommodate an unlimited number, and it is slightly cheaper, although it means taking a risk of disruption by rain.

Once the early sales of tickets have been measured, a final decision must be taken. The indoor concert can only proceed if the hall has already been booked. Even if it has been booked, it can be cancelled, although the deposit will be lost, and an outdoor concert planned instead. The full cost of the hall is £350, whilst the outdoor venue will cost £200 to set up. If the concert is cancelled, all tickets, selling for £3, will be refunded, but an insurance policy against rain is available, it costs £200, and will pay £1000 if it does rain.

Ticket sales expectations are as follows: if early sales are strong, then there is a 40% chance of selling 700 tickets, 40% chance of 500 and 20% chance of 300 tickets; weak early sales will indicate a 10% chance of selling 700 tickets, 50% chance of 500 and 40% chance of 300. The chance of strong or weak early sales is split 50–50. Should the Club book the hall?

APPENDIX 2

Program Loading Advice

A2.1 Spectrum Cassette Version

The Teaching Program is on Cassette No. 1 and the Applications Program is on Cassette No. 2. Both programs load and auto run by simply typing LOAD "" and ENTER.

A2.2 Spectrum Microdrive Version

The Teaching and Applications Programs both start on Cartridge No. 1. Simply insert Cartridge No. 1 in the Microdrive and key NEW ENTER RUN ENTER. An option to run the Teaching or Applications Program will then soon appear on the screen. However, the Teaching Program menu routine may ask you to insert Cartridge No. 2 in the Microdrive to load certain parts of the course. Please obey the instructions which you see on the screen.

A2.3 Commodore 64 Cassette Version

The Teaching Program is on Cassette No. 1 and the Applications Program is on Cassette No. 2. Both programs load and auto run by simply pressing SHIFT and RUN/STOP at the same time. The Teaching Program also loads in additional modules from the tape, and when it is doing this, a screen message may appear to instruct you to key in the word R U N followed by RETURN. Always read carefully and obey the instructions which appear on the screen.

Commodore 64 cassette version of this title employs the BURNER SYSTEM.

A2.4 Commodore 64 Disk Version

The Teaching and Applications Programs are on the same disk. Both programs operate by typing LOAD "M E N U", 8 RETURN When the program has loaded, a **READY** message will appear on the screen. Select the Teaching or Applications Program from the menu which then appears.

A2.5 Faster Cassette Access

The teaching course is in fact formed from a number of individual programs. The first program is a loader, which sets up the system parameters and the graphics characters. The teaching programs are called "demo" and "teach1" to "teach 9". These relate to the various chapters as follows:

demo – Chapter 2, A WORKED EXAMPLE
teach1 – Chapter 3, DECISION STRUCTURE
teach2 – Chapter 4, INSERTING THE VALUES
teach3 – Chapter 5, PROBABILITIES
teach4 – Chapter 6, EXPECTED VALUE
teach5 – Chapter 7, THE ROLL-BACK
teach6 – Chapter 8, RISK PROFILE
teach7 – Chapter 9, SENSITIVITY
teach8 – Chapter 10, VALUE OF INFORMATION
teach9 – Chapter 11, MORE PRACTICE

If your cassette recorder has a tape counter on it, you can use the facilities of your computer to find the counter reading for the start of each program. Then, when you wish to use a particular unit, you can simply follow these steps:

1) Load the first part of the teaching tape, and make your selection in the usual way. – You must do this to access the machine code sub routines.

2) Fast forward the tape to a point just before the start of the required program, and then set the recorder to "PLAY". On the Spectrum version, all the program units will start automatically once they are loaded.

This simple procedure could save you 15 minutes or more on loading the later modules.

APPENDIX 3

Summary of Keywords

Used on the Applications Program Menus

Add Allows you to add another branch to the node displayed on the screen. Will only be displayed if there are currently less than five branches defined.

Alter Calls the edit routine to permit you to alter any part of the tree displayed on the screen, except the left hand node.

Chain Links a copy of the contents of the memory onto the cursor node, if that node currently has no branches. The cursor node will change to the type saved at the start of the sub tree stored in memory.

Clear Clears the memory. The memory must be empty before another part of the tree is copied into it.

Copy Send a copy of everything on the screen to the printer.

Edit There will be one edit line on the menu for each branch displayed on the screen. Select the number of the branch you wish to change.

Erase Deletes the branch currently being edited, together with all branches beyond it.

EVSI Calculates the expected value of sample information for the particular chance node displayed at the left of the screen.

Go On Computer will continue requesting information to complete the definition of the tree. If it is complete, then it will recalculate EMV and return to the main menu.

Label Change the description on the particular branch being edited.

Node Change the node at the right hand end of the branch being edited. Altering a right hand node will destroy all branches beyond it.

Other Used when not all options can be displayed at once. **Other** will call a menu of alternative commands.

Prob Change the probability of the particular branch being edited.

Query Provides all the details of the node at the cursor position, and the branch to the left of that node.

Store Saves a copy of all of the tree linked to the right of the cursor node in the memory.

Study Display the cursor node and its branches in full, and presents the editing (and EVSI) menu.

Sub/T Displays an outline picture of the sub tree to the right of the cursor position. If a number is displayed adjacent to **Sub/T**, this indicates there are that number of sub trees not displayed on the screen due to lack of room.

Value Change the value of the branch being edited.

Whole Displays an outline picture of the entire tree, or as much of it as will fit on the screen.

Glossary

Action, an event which the decision maker can choose to cause to occur.

Bayes Theorem, is a method used to calculate the revised probability of an event when additional information becomes available.

Chance Node a point on a **Decision Tree** where the decision maker cannot choose what will happen next.

Decision Node, a point on a **Decision Tree** where the decision maker has full control over what is to happen next.

Decision Analysis, a method of selecting the best course of action through a complex sequential decision problem.

Decision Tree, the diagrammatic representation of a sequential decision problem.

Expected Monetary Value (EMV), the average value that a situation or event would have if it was repeated many times.

Expected Value of Perfect Information (EVPI), the increase in the **EMV** brought about by being able to predict with certainty the outcome of a series of otherwise chance events.

Expected Value of Sample Information (EVSI), the increase in **EMV** brought about by obtaining additional information about the probable outcome of a series of chance events.

Interactive, in computer terminology, the process whereby the function of the computer is dependent upon the responses of the user.

Maximin, a decision criterion by which the decision is made which has a worst outcome less severe than the worst outcome of any alternative course of action.

Outcome, the result of a Chance Event.

Payoff, the EMV of a terminal node on a **Decision Tree**, calculated by summing the costs and values of the sequence of events which leads to that node.

Probability, the measure of the chance that a particular event will occur. It is given by a number in the range of 0 (for impossible) to 1 (certain).

Risk Profile, a schedule of all the payoffs which can occur if only the highest value decisions are taken, together with their probabilities.

Roll-back, the process of calculating the **EMVs** of all the nodes of a **Decision Tree**, in sequence, from the last to the first.

Sensitivity, a measure of how much the basic costs, values and **probabilities** need to change to alter the preferred decision.

Bibliography

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